

EVALUATION OF RUST COMPATIBLE PRIMERS FOR MARINE APPLICATIONS

MAY 1984

Prepared by
RENSSELAER POLYTECHNIC INSTITUTE
IN COOPERATION WITH
AVONDALE SHIPYARDS, INC.

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE MAY 1984		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Evaluation of Rust Compatible Primers for Marine Applications				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Building 192 Room 128 9500 MacArthur Bldg Bethesda, MD 20817-5700				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 63	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

TABLE OF CONTENTS

	Page
LIST OF TABLES	ii
LIST OF FIGURES	iii
FOREWORD.	v
EXECUTIVE SUMMARY	vii
1. CONCLUSIONS AND RECOMMENDATIONS	1-1
1.1 Project Results.	1-1
1.2 Recommendations.	1-2
2. TECHNICAL APPROACH.	2-1
2.1 Program Rationale.	2-1
2.2 Literature Search.	2-1
2.2.1 Discussion of Treatments.	2-2
2.3 Problem Areas.	2-3
3. RESULTS.	3-1
3.2 Surface Preparation.	3-2
3.3 Materials Tested	3-4
3.4 Salt Spray Evaluation.	3-4
3.4.1 Blister Rating.	3-6
3.5 Salt Water Immersion Test Method	3-15
3.5.1 Immersion Tests Results	3-15
3.6 Hydrostatic Cyclic Exposure Test	3-23
3.6.1 Test Results.	3-23
3.7 Bond Strength Evaluation	3-26
3.7.1 Bond Strength Results	3-32
3.8 Overall Results.	3-32
REFERENCES.	3-35
APPENDIX A	A-1
APPENDIX B.	B-1
APPENDIX C.	c-1

LIST OF TABLES

	Page
Table I Rust Compatible Materials.	3-5
Table II Salt Spray.. . . .	3-7
Table III Immersion Test.	3-16
Table IV Results of the Hydrostatic Exposure Test	3-24
Table V Bond Strength Results Before and After Exposure to 1000 Hours in Salt Water.	3-34

LIST OF FIGURES

		Page
Figure 3.0	Typical Rusted Test Specimen Surface on Which the Rust Compatible Primers Were Evaluated.	3-3
Figure 3.1	Condition of the Mastic Coating Applied to a Rusted Surface. Photograph Taken after 6000 Hours in a Salt Spray Environment.	3-9
Figure 3.2	Condition of the Water Based Epoxy Mastic System After 6000 Hours of Exposure to Salt Spray Environment.	3-10
Figure 3.3	Overall Condition of Test Specimen Coated with the Latex Rust Converter After Exposure to Salt Spray.	3-11
Figure 3.4	Condition of the Urethane Primer with Durathane Top Coats after 6000 Hours in Salt Spray	3-12
Figure 3.5	Condition of the Chlorinated Rubber Primer After 500 Hours in Salt Spray Environment.	3-13
Figure 3.6	Condition of the Coal Tar Epoxy Coated Specimen on Grit Blasted Steel After 6000 Hours of Exposure to a Salt Spray Environment	3-14
Figure 3.7	Condition of the Latex Base and Water Based Epoxy Coating After 1500 Hour Immersion in Salt Water (Magnification approx. 3X).	3-17
Figure 3.8	Condition of the Solvent Based Epoxy Coating After 1500 Hours Immersion in Salt Water (magnification approx. 3x)	3-18
Figure 3.9	Condition of the Urethane and Chlorinated Rubber Primer After 1500 Hours Immersion in Salt Water (magnification approx. 3X)	3-19
Figure 3.10	Condition of Urethane Primer with Various Top Coats After 1500 Hours Immersion in Salt Water (magnification approx. 3X)	3-20
Figure 3.11	Condition of Latex Conversion Primer with Various Top Coats After 1500 Hours Immersion in Salt Water (magnification approx 3X).	3-21
Figure 3.12	Condition of Penetration Primer and Standard Coal Tar Epoxy After 1500 Hours of Immersion in Salt Water (magnification approx. 3X)	3-22

		Page
Figure 3.13	Condition of the Mastic Coatings After 50 Cycles of Exposure to 20 Psi Water Pressure.	3-27
Figure 3.14	Condition of the Latex Conversion Primer After 50 Cycles of Exposure to 20 Psi Water Pressure. .	3-28
Figure 3.15	Condition of the Chlorinated Rubber and Urethane Primer After 50 Cycles of Exposure to 20 Psi Water Pressure.	3-29
Figure 3.16	Typical Condition of the Penetration Primer Coated Specimen After 60 Cycles of Exposure to 20 Psi Water Pressure.	3-30
Figure 3.17	Condition of Various Control Test Specimens After 50 Cycles of Exposure to 20 Psi Water Pressure. .	3-31
Figure 3.18	Schematic Diagram of the Essential parts of the Bond Strength Apparatus	3-33

FOREWORD

This report is the result of one of the many projects managed and cost shared by Avondale Shipyards, Inc. under the auspices of the National Shipbuilding Research Program. The program was a cooperative effort with the Transportation Department, Maritime Administration Office of Advanced Ship Development.

On behalf of Avondale Shipyards, Inc., Mr. John Peart was the Program Manager responsible for technical direction and publication of the final report. Program definition and guidance were provided by the members of the Society of Naval Architects and Marine Engineers Ship Production Committee Panel 023-1, Surface Preparation and Coatings.

The experimental work described in the report was done at Rensselaer Polytechnic Institute, (RPI) Troy, New York under the direction of Mr. S. J. Calabrese, Research Specialist.

In addition, acknowledgement is given to the coating manufacturers who participated in the program by submitting samples. They were:

Devoe

Bywater Sales & Service Co., Inc.

Applied Coatings Technology, Inc.

Rust-Oleum Industrial Coatings Systems

The principle objective of the program was to determine the state-of-the-art of primers and/or coating systems which were designed to be applied directly to a rusted surface, and to determine through laboratory evaluations if any of the materials performed sufficiently well enough to be used in marine application.

If such materials can be utilized for shipboard corrosion control, meaningful cost savings can be achieved in ship construction through reduced man-hours for surface preparation and maintenance.

EXECUTIVE SUMMARY

The possibility of applying an adherent coating to a rusted surface has been of interest for several years. Escalating surface preparation costs, plus inaccessibility, are dictating the need for primers which are rust compatible. Regardless of the price paid for a marine coating, if the surfaces are poorly prepared or the areas to be coated are difficult to reach with surface preparation equipment, the coating will suffer due to adhesion problems. Rerusting after primary surface preparation and the complete removal of oxides in pitted and hard to get-at areas, is very difficult and costly during construction and maintenance respectively.

Unique methods of preparing the surface by: A) chemical cleaning with citric acid [1], and B) absorption of rust into an easily removable coating [2] show promise, but are not routinely used at this time.

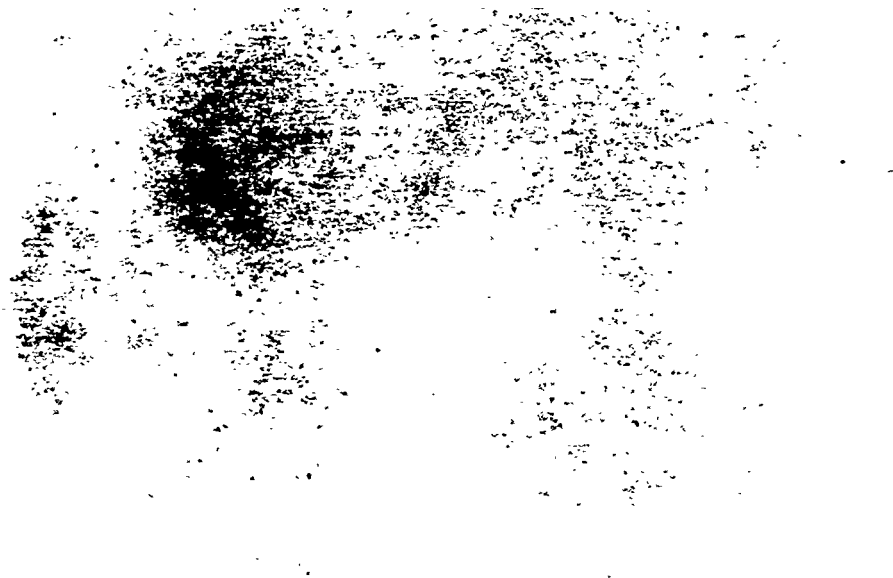
A few industrial and marine coating companies have developed coatings which are manufactured explicitly for the purpose of applying them to a rusted surface. Several companies responded with coatings which are presently on the market for other purposes and would have been willing to allow RPI to evaluate them for rust compatibility. However, it was not the intention of this program to evaluate various materials for application to a rusted surface, but rather to evaluate those coatings which were manufactured and marketed specifically for the purpose of applying them to a rusted surface. Hence, the relative value of these coatings could be established and, if the results were encouraging, the manufacture of the rust compatible primers could be developed.

One coating was very successful in the evaluations and a second showed promise.

The majority of the tests utilized were severe, being those associated with the evaluation of materials for immersion service, thus enhancing the possibility of their use in less severe corrosion areas.

SECTION 1

Conclusions And Recommendations



1. CONCLUSIONS AND RECOMMENDATIONS

1.1 Project Results

The purpose of this project was to establish the merit of commercially available coatings which were manufactured specifically for application to rusted surfaces.

In order to determine the relative differences in the coatings the following tests were utilized:

- I Salt spray exposure for 5000 hours
- I Fresh water immersion tests
- I Hydrostatic cyclic exposure
- I Adhesion tests

The results and conclusions of these tests are summarized as follows.

The concept of applying a coating directly to a rusted surface appears to have merit.

- A stabilization type epoxy coating gave excellent results in all of the tests.
- The epoxy coating which gave the best results was a solvent base material. Similar latex base and water-base epoxies were less successful but may possibly be useful for less severe service than immersion.

Encouraging results were also obtained from a polyurethane primer.

From preliminary results it appeared that coatings which were manufactured to stabilize the existing rust were superior to the conversion and penetration type systems.

1.2 Recommendations

A. The solvent base epoxy coating showed sufficient merit to warrant further evaluations for immersion and atmospheric service.

Possible options to accomplish this are as follows:

- 1) Application of test patches in ship's ballast tanks, underwater hull and top sides.
- 2) Application in test tanks that simulate ship's ballast cycles.

B. A program with an expanded work scope to evaluate rust compatible materials is presently in progress. That program is being sponsored by the Federal Highway Administration of the Transportation Department and is evaluating materials for use on bridges. The most promising materials identified by their evaluation and the polyurethane primer that showed superior performance in these tests should be top coated with compatible marine systems for evaluation on a structure subjected to marine atmosphere exposure.

C. It should be noted that these coatings were evaluated over rust formed by fresh water immersion. Corrosion investigators have established that soluble salt contamination of the substrate results in the reduction in coating life. This reduction in coating life with respect to a threshold of contamination has not been quantified. Additionally, the effect of rust composition and structure on coating adhesion has not been characterized. Work in these areas should be initiated.

SECTION 2

Technical Approach



2. TECHNICAL APPROACH

2.1 Program Rationale

In order to reach the goal of this program, the following steps were taken:

- A literature search was performed on rust compatible primers in order to determine the following:
 - .history
 - .method of protection
 - .state of the art.
- A survey of industrial and marine coating manufacturing companies was made regarding products which were presently on the market.
- Test specimens were prepared by producing a uniformly rusted surface and sent to the manufacturers who had responded positively to the above.
- After the specimens were coated and returned, they were put into the various test fixtures for evaluation.

2.2 Literature Search

The literature search produced very interesting results in that a significant part of the history of rust compatible primers took place in Europe. Many U.S. companies were interested in the process but there did not appear to be a serious contribution forthcoming until the mid 70's. A listing of references concerning the subject is given in Appendix A. Unfortunately some of the papers have not been translated into English.

The most accepted methods of treating a rusted steel surface is by adding ingredients to the coating to accomplish one or more of the following:

- rust conversion
- rust stabilization
- penetration.

2.2.1 Discussion of Treatments

Rust conversion products are used to convert the rust from iron oxide to another Fe compound. The most common approach is to use phosphoric acid. In that instance, the various compounds of iron and oxygen which make up rust (FeO , Fe_2O_3 , etc) are converted to compounds of Fe and P. There are several published reports in which the chemical reaction is fully described [2]. This method, of course, is based on the assumption that the only elements in the rust compound are Fe and O. The corrosion product formed in steel can contain some of the alloying agents in the **steel and some of the impurities in the air**. In addition, impurities from pollution products can add to the reaction. Hence the formulation of rust from different parts of the country can vary considerably.

The second type of rust treatment, in which a primer reacts with rust, is the stabilization type. In this instance, the primer reacts with the rust to form a more stable compound of Fe and O. Reference 3 discusses the reaction which takes place in stabilizing the rust to change it from various forms of iron oxide to Fe_3O_4 (magnetite). In that paper, a less common type of rust primer is described in which soluble salts in the rust are converted to inert compounds. However, presently there are products on the market which are designed to stabilize the rust to Fe_3O_4 and these

appear to accomplish this goal. It should be noted that the reaction takes a considerable length of time. Nine to twelve months are typical reaction times. It should also be noted that this type of product was the most successful in this program.

The third treatment method is to penetrate the rust by means of an oil and use a top coat to protect the remaining steel substrate and prevent further corrosion. Barrier tiecoats or top coats are used to prevent additional moisture from attacking the surface to produce further rust damage.

In all three treatments, it is necessary to prevent penetration of moisture which would restart corrosion damage

2.3 Problem areas

Though each type of coating is designed to treat the surface to prevent further damage, there are associated problems.

A conversion coating must have enough converter to react with all of the rust on the surface immediately. If unconverted rust remains, poor bonding will result which will cause coating blisters and eventual failure.

Stabilization coatings must also contain enough material to react with the existing rust to form Fe_3O_4 . Since the reaction occurs slowly, full protection is not accomplished for a considerable length of time.

The penetration coating usually contains a penetrating oil. This oil does not dry readily and a strongly adherent bond is not an easy accomplishment.

SECTION 3

Results



3. RESULTS

3.1 Contact Suppliers

Suppliers of marine coatings were contacted concerning the goals of the program and the possibility that they might have a product which should be evaluated. A list of those companies and their representatives is given in Appendix B.

The response was somewhat surprising in that only a few had products which were on the market. Some were evaluating materials in the laboratory but were not ready to market the product as yet.

Several had products which could be evaluated but were not designed as rust compatible. Because of the time and cost for specimen preparation, it was not in the best interest of the program goals to evaluate materials which were not formulated for direct application to a rusted surface.

Those companies who submitted a positive response to the inquiry were contacted concerning the type of coating they had and the method of application. In order to eliminate application problems, the vendor was asked to apply the coating to specimens which were prepared at RPI. In the event that the manufacturer did not have an applicator, the product was shipped to RPI and applied in accordance with the manufacturer's instructions.

After the specimens were prepared they were shipped to the vendor for coating. Each vendor was asked to provide their data sheets and the coating applicator technique by filling out an information sheet for each coating system submitted. A copy of the information sheet is shown in Appendix C.

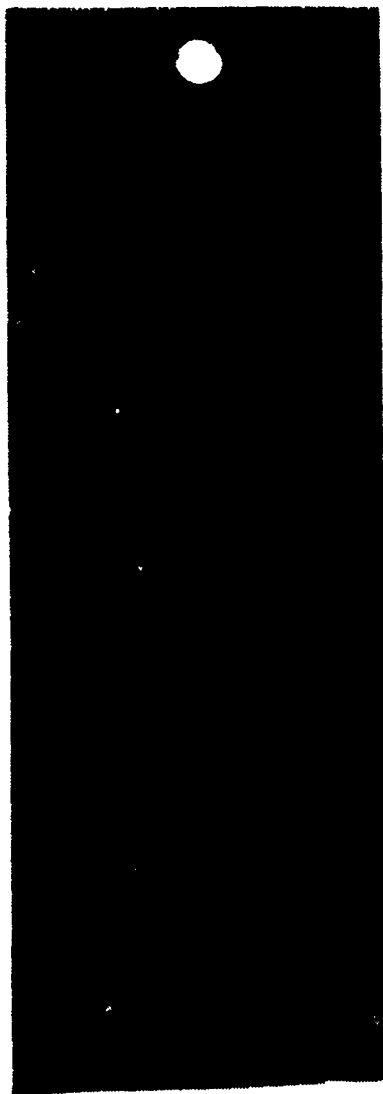
After the samples were returned to RPI, one specimen from each batch was sectioned and examined under the microscope to ensure that the surface still contained the original rust. This, of course, was to ensure that one coating did not have an unfair advantage over the others.

It should be understood that if the manufacturer had a complete coating system which he felt was optimum, he was asked to apply it. He was also asked to apply each coat at what he felt was the optimum thickness. Hence the coating evaluated was applied under the best possible conditions and at the recommended coating thicknesses. The other point of interest was the possibility of changing the top coat. If the rust compatible primer could be used with various generic base top coats, they were evaluated with more than one type top coat. Therefore, some of the systems evaluated will contain one primer with various standard marine top coats.

3.2 Surface Preparation

Two methods were evaluated to prepare the surface with a even coat of rust. The first method was to place the specimen on a rack in an outdoor environment. At three day intervals they were flipped over to ensure that both sides were evenly coated. Unfortunately, varying weather conditions, particularly changes in humidity, provided a uneven rate of rust formation. This method was abandoned in favor of the method described below.

The specimens were placed in a circulating continuously aerated water bath. After a period of six weeks, the specimens were completely coated with an even coat of red rust. They were then scrubbed with a coarse brush to remove the loose rust from the surface. Figure 3.0 shows a typical rusted surface on which the vendor was asked to apply the candidate coating. They were then packed in plastic bags and shipped to the vendor.



Approx. 1X Mag.



Magnification 5X

Figure 3.0 Typical rusted test specimen surface on which the rust compatible primer was evaluated.

3.3 Materials Tested

Table I shows the types of primer coatings selected for evaluation. In addition, the coating thickness, rust prevention function and need for top coat is listed. Note that the first three are mastic types, applied directly to the rusted steel. They are used as "high build" materials with no top coat. The rest are primer types and are applied with additional over coats. In some cases, the top coat was also a product of the primer manufacturer. Standard marine coatings were used where the primer manufacturer did not recommend a particular top coat product, standard marine coating were used. Hence, the first three materials are the entire coating systems while the rest were evaluated with various top coats.

3.4 Salt Spray Evaluation

The salt spray evaluation was run to determine the ability of the coatings to protect the substrate against further corrosion.

The test was performed in a Singleton Corrosion Test Cabinet in accordance with ASTM-B117-73. (Reapproved 1979)

The test conditions were as follows:

Salt solution pH -	6.5 to 7.2
Test temperature -	95°F (35°C)
Test duration -	6000 hrs

The specimens were photographed and placed in the cabinet. At 200 hour intervals they were examined for signs of coating degradation. Changes in the coating were recorded during each examining period.

Table II shows the results of the salt spray evaluation. In addition, the number of top coats are shown accompanied by the thickness of each coat. The blister rating of each material is given in accordance with the ASTM Standard D714. Note that the rating is shown after 1000 hours and at the end of the test.

TABLE I
RUST COMPATIBLE MATERIALS

Material	Type	Function	Thickness	Top coat
Latex	Mastic	Stabilization	.040	None
Epoxy-water base	Mastic	Stabilization	.020	None
Epoxy-solvent base	Mastic	Stabilization	.014	None
Rust-converter latex	Sprayable coating	Conversion	.002	Various
Urethane	Sprayable coating	Stabilization	.002	Various
Vinyl	Sprayable coating	Conversion	.002	Various
Chlorinated rubber	Sprayable coating	Conversion	.002	Various
Fish oil penetrator, alkyd	Sprayable coating	Penetration	.002	Alkyd

In order to assess the amount of damage seen on the candidate materials, a set of control tests were run with standard marine coatings on a grit blasted steel surface. These results are shown at the end of Table II.

The various candidate coatings gave a large difference in overall appearance. Of all the materials tested the solvent based epoxy gave the most promising results. This was the mastic material described earlier. Both of the other mastics held up very well for the first 5000 hours but eventually showed blistering by the end of the test. Figures 3.1 and 3.2 show the condition of mastic coated test specimens at the end of 6000 hours.

The test hours column in Table II gives the total amount of exposure hours for each test specimen. If the specimens had severe rust through or blistering in the early stages of testing, they were removed from the cabinet since failure was imminent. Hence, it should be noted that the mastics, urethane and the control specimens were the only materials to survive the 6000 hours of testing. In addition, the latex conversion coating with the chlorinated rubber also remained on test for the entire time but did not appear as encouraging as some of the others.

Figures 3.3-3.6 show the condition of the other specimens at the end of the test.

3.4.1 Blister Rating

The blister rating was performed in accordance with ASTM Standard D714. The degree of blistering is done by comparison with photographic standards as described in the specification.

The standards represent two characteristics of blisters, size and frequency. Size is described by an arbitrary scale of from 0 to 10.

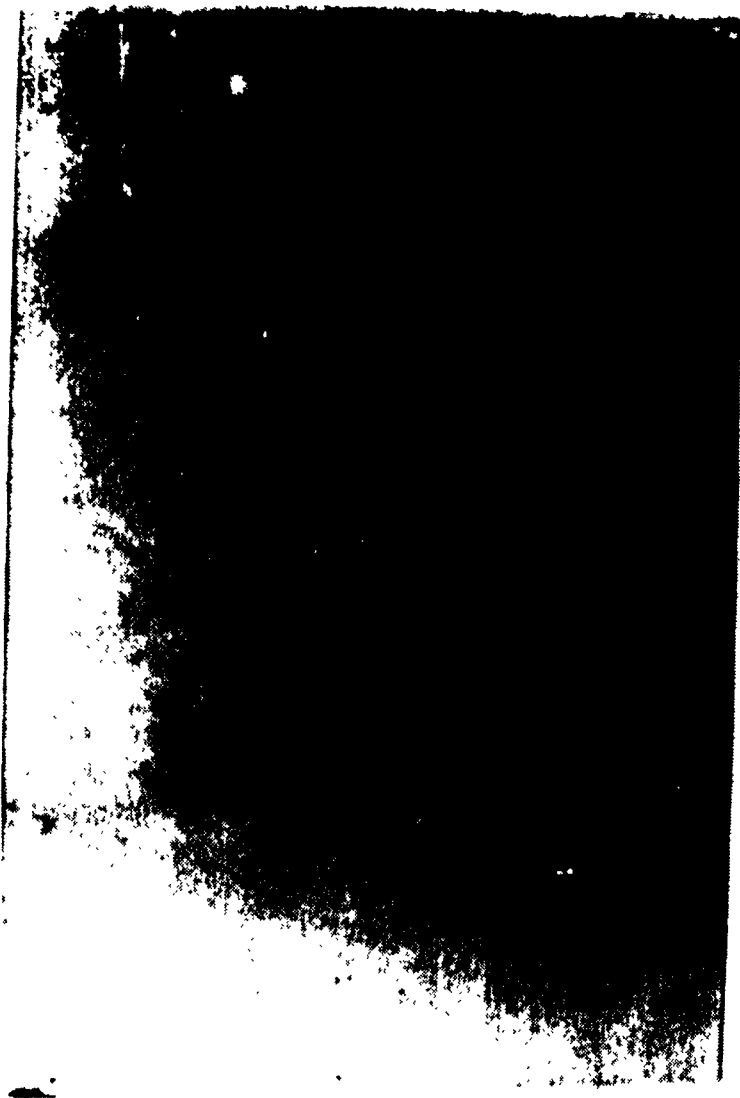
TABLE II
SALT SPRAY

Material	Primer Treatment	No. of Coats	Total DFT Mil's		No. of Coats	Total DFT Mil's	Test Hours	ASTM D 714 Blister Rating After 1000 Hrs	End	
Rust Bar 210	Latex	2	40	None			6000	2 Few	2 Medium Edge deterioration after 500 hrs	
Rust Bar 211	Epoxy Water Base	2	20	None			6000	None	2 Few Edge deterioration after 580 hrs	
Rust Bar 235	Epoxy-Solvent Base	2	14	None			6000	None	None Surface excellent	
Rust Converter	Latex	2	2	Chlorinated Rubber	1 1	Primer Top Coat	4 2	6000	2 Few	2 Dense
Rust Converter	Latex	2	2	Epoxy	1 1	Primer Top Coat	4 2	3000	4 Few	4 Dense Severe rust through
Rust Converter	Latex	2	2	Alkyd	1 1	Undercoat Top Coat	1.5 1.5	1000	-	Rust through
Byco 950	Urethane	1	2	Durathane 900	1		4	6000	-	Light rust on edge
Byco 950	Urethane	1	2	Durathane 902	1		3	6000	-	Light rust on edge
Byco 250	Vinyl Copolymer	1	2	Alkyd	1		3	300	-	Rust through

TABLE II (Cont)

Material	Primer or Treatment	No. of Coats	Total DFT Mils	Top Coat	No. of Coats	Total DFT Mils	Test Hours	ASTM D 714 Blister Rating		Remarks
								After 1000 Hrs	End	
Byco 600	Chl orinated Rubber	1	2	Al kyd	1	4	500	-		Rust through
Rustol eum 769	Penetrati on Pri mer	2	2	Al kyd	2	4	240	-		Materials peeled between top coat and primer
Rustol eum 769	Penetrati on Pri mer	2	3	Al kyd Rust Inhi bi tor	2	4				
Rustol eum				Al kyd Top Coat	1	2	240	-		Peeled between primer and rust inhibitor
STANDARD COATING ON PREPARED GRIT BLASTED STEEL										
Chl ori nated Rubber	Carbol i ne	1	2.5	Chl ori nated Rubber	2	4	6000	None	6 Few	Some rust bleed through
Pol yami de Epoxy	Carbo Zi nc II	1	2.5	Pol yami de Epoxy	1	5	6000	None	None	Some rust bleed through
Coal Tar Epoxy				Coal Tar Epoxy	2	12	6000	None	6 Few	Light rust through

*DFT - Dry Film Thickness

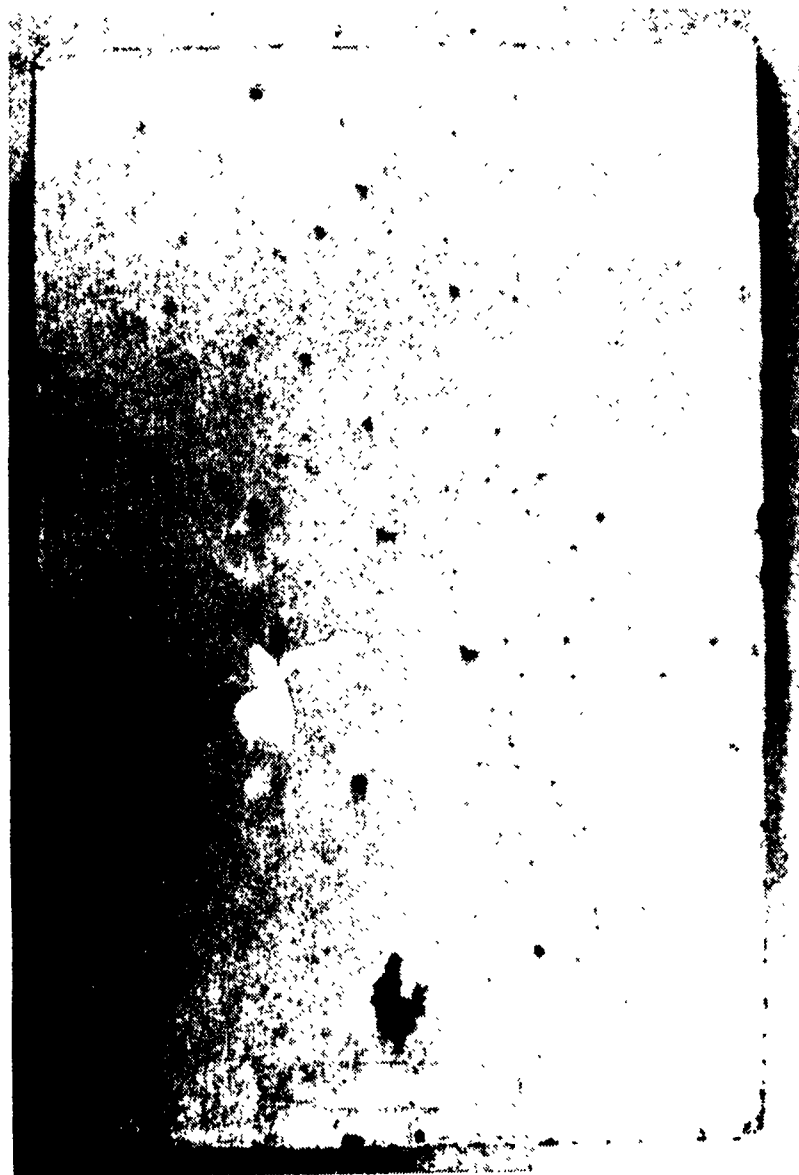


Rust Bar 235
Solvent Based
Epoxy



Rust Bar 210
Latex Based
Epoxy

Figure 3.1 Condition of the Mastic coating applied to a rusted surface.
Photograph taken after 6000 hrs. in a Salt Spray environment.



Rust Bar 211

Figure 3.2 Condition of the water based epoxy mastic system after

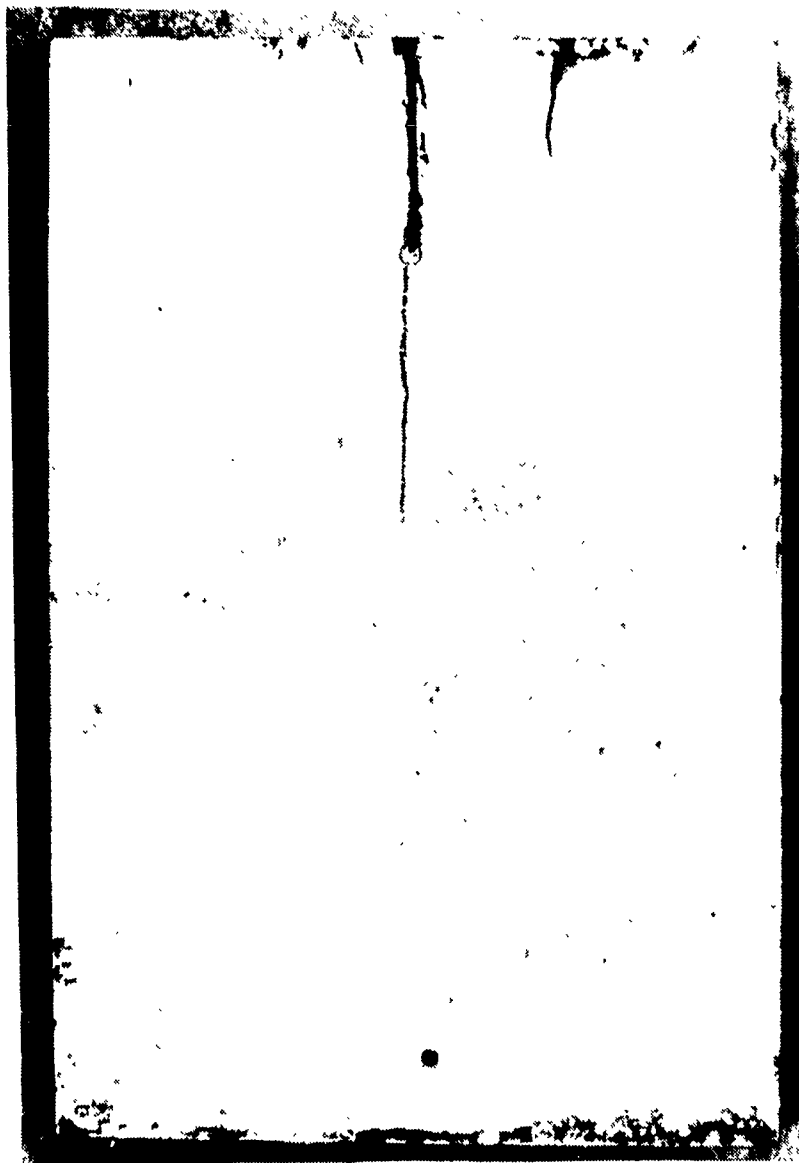


Chlorinated Rubber Topcoat
6000 hours exposure



Epoxy Topcoat
3000 hours of testing

Figure 3.3 Overall condition of test specimen coated with the Latex rust converter after exposure to salt spray.



Durathane 900



Durathane 902

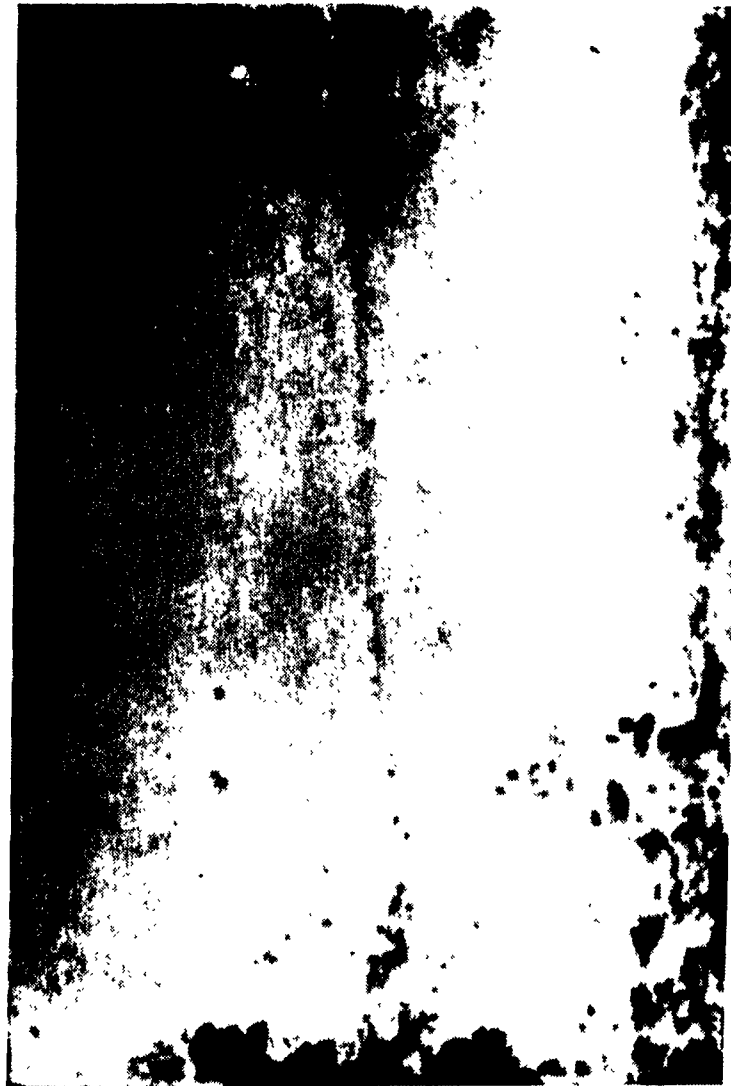


Figure 3.5 Condition of the Chlorinated Rubber Primer after 500 Hours in Salt Spray Environment.



Figure 3.6 Condition of the Coal Tar Epoxy Coated Specimen on
Grit Blasted Steel after 6000 Hours of Exposure to

The size decreases with increasing number, No.8 is the smallest size which can be seen with the unaided eye. Frequency is described quantitatively in four steps : dense, medium-dense, medium and few.

3.5. Salt Water Immersion Test Method

The second evaluation performed on the candidate coatings was a simple immersion test where the coatings were scribed on the diagonal across the specimens and allowed to soak in a water solution containing 5% sodium chloride for several hundred hours. The depth of undercutting or creep was measured and rated in accordance with ASTM Standard D1654 Method A. Creepage is the amount of corrosion which takes place beneath the coating from the edge of the scribe line. The range is a rating from 00 (1 inch) to 10 (1/64 inch).

3.5.1 Immersion Tests Results

The results of the immersion tests are shown in Table III. This tabulation shows the candidate coating materials, the thicknesses for the various coats, the creepage rating at 500 and 1500 hours and a blister rating where applicable.

As with the salt spray test, the mastics gave the most promising results with the solvent based epoxy again being the best. The scribed edge of the latex base material appear to be deteriorating with slight discoloration at the edge interface.

Notice too that the urethane coating systems also gave encouraging results. In one instance, only the urethane primer was applied, with no top coat. It too showed only slight creepage after 1500 hours.

Figure 3.7 shows the condition of the water base epoxy and the latex mastic systems. Figure 3.8 shows the condition of solvent based epoxy system. Figure 3.9-3.12 show the condition of some of the other materials as they appeared after test.

TABLE III
IMMERSION TEST

3-16

Material	Primer Treatment	No. of Coats	Total DFT Mils	Top Coat	Coats	Total DFT Mils	Scribe (ASTM D1654-Method A) 500 hrs	Creepage Standard (Method A) 1500 hrs	Remarks
Bar Rust 235	Epoxy Solvent Base	2	14	-			9	9	Excellent
Bar Rust 211	Epoxy Water Base	2	20	-			8	7	Corner chipped
Bar Rust 210	Latex Latex	2	40	-			9	8	Edge deteriorated
Byco 600	Chlorinated Rubber	1	2	Alkyd	1	4	7	5	Coating blistered, size medium dense
Byco 950	Polyurethane	1	2	Polyurethane	1	4	9	9	Blister size No. 2, few
Byco 950	Polyurethane	1	2	Alkyd	1	3	9	9	Excellent
Byco 950	Polyurethane	1	2	None			9	7	Slight edge deterioration
Rust Converter	Conversion	2	4	Alkyd	2	8	7	4	Blisters, size No. 6, dense
Rust Converter	Chlorinated Rubber	1	3	Chlorinated	1	2	8	4	Blister, size No. 8, dense
Rust Converter	Latex Conversion	2	4	Epoxy	2	8	4	2	Blister, size No. 8, few
Rustoleum 769	Fish Oil Penetrator	2	2	Alkyd	2	4	2		Coating removal between the primer and top coat
Coal Tar	Solvent				2	12	8	4	No blister



Latex Base



Water Base

Figure 3.7 Condition of the Latex base and water based epoxy coating after 1500 hour immersion in salt water (magnification approx. 3X).



3.8 Condition of the solvent based epoxy coating after 1500 hours immersion in salt water (magnification approx. 3X).



Urethane



Chlorinated Rubber

Figure 3.9 Condition of the urethane and chlorinated rubber primer after 1500 hours immersion in salt water (magnification approx. 3x).

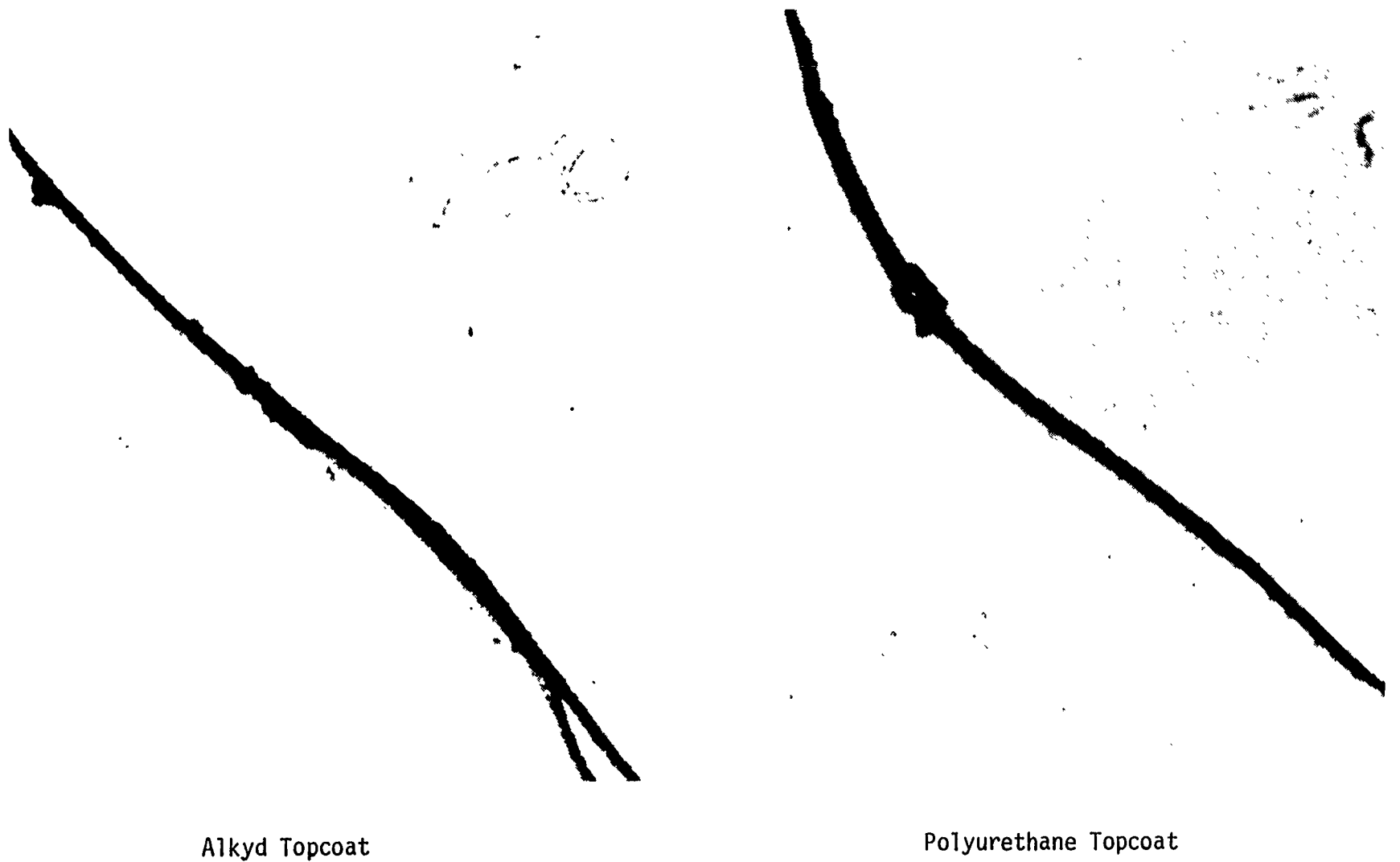


Figure 3.10 Condition of urethane primer with various top coats after 1500 hours immersion in salt water (magnification approx. 3X).



Chlorinated Rubber Topcoat



Alkyd Topcoat

Figure 3.11 Condition of Latex Conversion primer with various top coats after 1500 hours immersion in salt water (magnification approx. 3X).



Penetration Primer



Standard Coal Tar Epoxy

Figure 3.12 Condition of penetration primer and standard coal tar epoxy after 1500 hours of immersion in salt water

3.6 Hydrostatic Cyclic Exposure Test

The final exposure type test was simple water immersion in a pressure tight box. Air pressure was introduced into a box and cycled between ambient and 20 psi at a cycle rate of 10 minutes.

This type of test has been used in the past for evaluation of ballast and fresh water storage tanks [1]. The usual cycle time is as long as 20 days. However, it was found that the short duration (10 minutes) and cyclic pressure produced adequate results for evaluating the specimens in this program. Air pressure was introduced at the rate of 20 psi in one minute. The pressure was held for 10 minutes and reduced at the same rate. After five cycles, the tank was uncovered and observations were made and recorded for each test specimen. The tank was recovered and another series of five cycles was run. This procedure was repeated for a total of 50 cycles.

3.6.1. Test Results

Table IV shows the results of the evaluation. As with the salt spray test, the specimens were rated in accordance with ASTM/D714 blister rating. Table IV show the condition of the surface after 10 cycles and at the end of the test (50 cycles). As in the previous tests, the solvent based epoxy gave the most promising results.

One specimen which did not appear good in the other tests gave surprisingly good results in this evaluation. The Latex rust converter with an epoxy top coat appeared unchanged. However, after it had been setting in the laboratory for approximately 500 hours, the coating cracked and disbonded from the surface, as seen in Figure 3.14.

TABLE IV
RESULTS OF THE HYDROSTATIC EXPOSURE TEST

Material	Primer Treatment	No. of Coats	Total DFT Mils	Top Coat	No. of Coats	Total DFT Top Coat Mils	ASTM D 714 Blister Rating		Remarks After Test
							After 10 Cycles	After 50 Cycles	
Rust bar 210	Latex	2	40	None			Edge Rusting	None	Some rust bleed through
Rust Bar 211	Epoxy Water Base	2	20	None			Edge Rusting	None	Some rust bleed through
Rust Bar 235	Epoxy Solvent Base	2	14	None			Edge Rusting	None	Some rust bleed through
Byco 950	Polyurethane	1	2	Durathane	1	4	No. 4 to No. 8 Med. -Dense	No. 4 Dense	No rust through but severe blistering
Byco 600	Chlorinated Rubber	1	2	Alkyd	1	4	None	No. 8 Few	" " " "
Byco 950	Polyurethane	1	2	Alkyd	1	3	No. 3 each No. 8 each	No. 4 No. 4 Same	Some signs of slight rust
Rust Converter	Latex Converter	2	2	Epoxy	2	8	Excellent	None	Failed after 500 hours, disbandment at the steel substrate
Rust Converter	Latex Converter	2	2	Vinyl	3	7	No. 4	Same	Several blisters on the entire surface
Rust Converter	Latex Converter	2	2	Chlorinated Rubber	3	9	No. 4 Med. -Dense	Same	Heavy rust bleed through
Rustol eun 769	Penetrating Primer	2	2	Alkyd	2	4	No. 6 Dense	No. 6 Dense	Poor bond between primer and top coat
Rustol eum 769	Penetrating Primer	2	2	Epoxy	1	4	No. 6 Dense	No. 6 Dense	Poor bond between primer and top coat

RESULTS OF THE HYDROSTATIC EXPOSURE TEST - continued

Material	Primer Treatment	No. of Coats	Total DFT Mils	Top Coat	No. of Coats	Total DFT Top Coat Mils	AST D 714 Blister Rating		Remarks After Test
							After 10 Cycles	After 50 Cycles	
CONTROL SPECIMEN ON GRIT BLASTED STEEL									
Bi tumi nous Epoxy	-				1	12	Excell ent	None	
Carbol ine	Carbo Zinc Inorgani c Zn	1	2.5	Epoxy Pol yami d	1	5	Excell ent	None	Li ght rust bleed through
Vi nyl	Inorgani c Zn	1	2.5	Vi nyl	1	3	Excell ent	8 each No. 8	

Figure 3.13-3.17 show the condition of the test specimens after 50 pressure cycles at 20 psi. As with the other tests, the mastics were the most encouraging with the polyurethane primer coated specimens being second best.

3.7 Bond Strength Evaluation

The bond strength of the candidate coatings was measured before and after exposure to a salt water environment. The technique used is similar to the Meredith-Guminski adhesion-test described in Ref. 4 and shown in Fig. 3.18.

The essential parts of the test fixture consist of a test specimen coated with the candidate coating system, a set of cylinders which were adhered to both sides of the test specimen and loading grips attached to each cylinder by means of an alignment pin.

The tensile strength was recorded at the time that the cylinder was pulled from the coating and the location of failure was noted.

The position of fracture is very important in this test. Separation in the fixturing epoxy gave a minimum value of bond strength. That is, the bond strength of the coating system is greater than that shown when fracture occurred. Separation in the top coat, or in the interface between the primer and the metal substrate gave an indication of the strength of the coating system. The criteria are as follows:

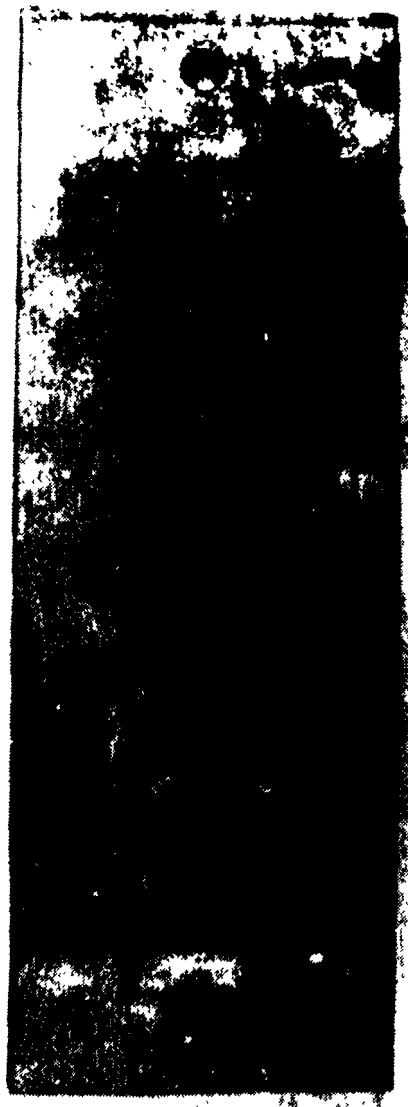
Separation in the epoxy minimum bond strength value
of the system

Separation in the top coat - cohesion failure of the top coat

Separation in the interface between the primer and the top coat-
adhesion failure of the top coat primer

Separation in the primer - cohesion failure of primer

Separation in the interface between the primer and the metal
substrate-adhesion failure of the primer/metal



Solvent Based
Epoxy



Water Based
Epoxy



Latex
Epoxy

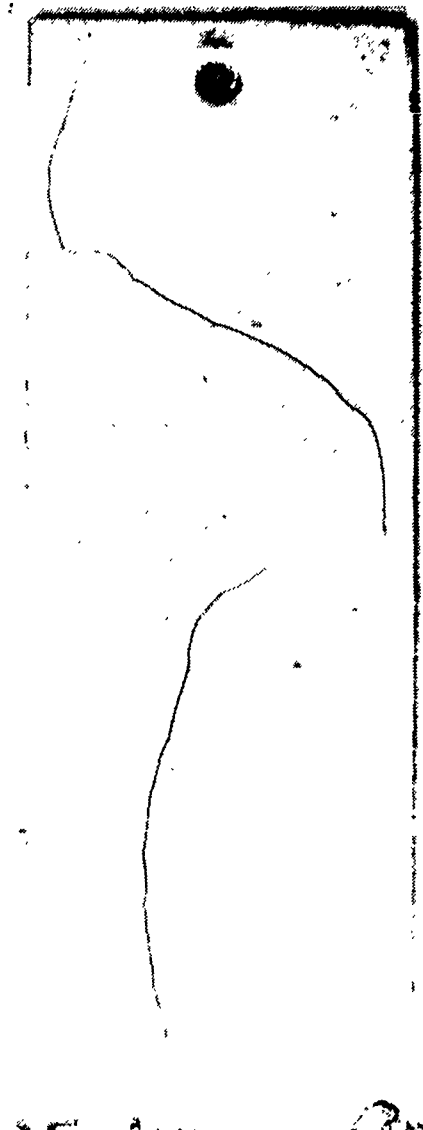
Figure 3.13 Condition of the mastic coatings after 50 cycles of exposure to 20 psi water pressure.



Chlorinated Rubber
Topcoat



Vinyl Topcoat

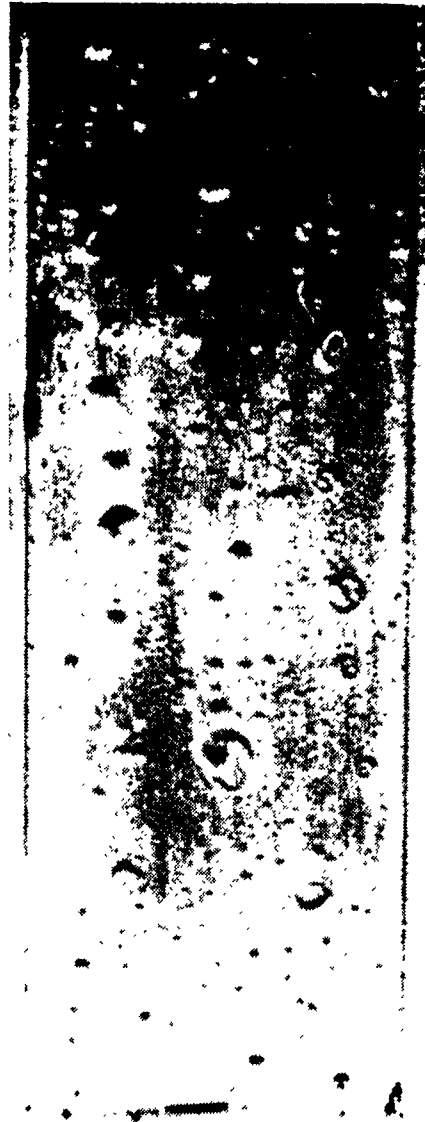


Epoxy Topcoat

Figure 3.14 Condition of the Latex conversion primer after 50 cycles of



Chlorinated Rubber



Urethane/Alkyd
Topcoat



Urethane/Polyurethane
Topcoat

Figure 3.15 Condition of the Chlorinated Rubber and urethane primer after 50 cycles of exposure to 20 psi water pressure.



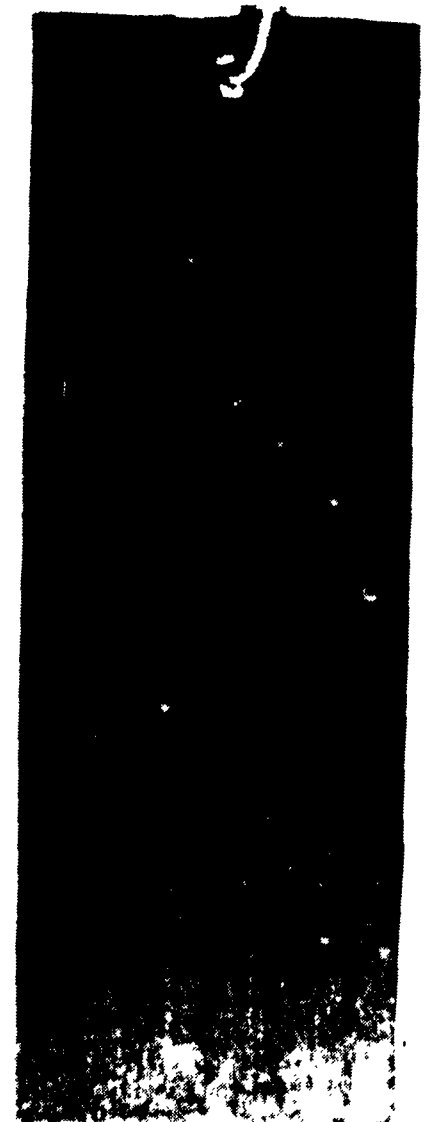
Figure 3.16 Typical condition of the penetration primer coated spe
after 50 cycles of exposure to 20 psi water pressure.



Inorganic Zn/
Epoxy Topcoat



Bituminous Epoxy



Inorganic Zinc/
Vinyl Topcoat

Figure 3.17 Condition of various control test specimens after 50 cycles of exposure to 20 psi water pressure.

Each specimen was placed in a salt water tank for 1000 hours and the bond strength remeasured.

3.7.1 Bond Strength Results

The results of the bond strength evaluations are shown in Table V. Except for the solvent based epoxy mastic, they all showed a significant reduction in strength after exposure to the salt water environment.

The fish oil penetration system never developed a very high bond strength to the top coat but the primer itself appears to be protecting the surface from further corrosion. Notice that the failures before and after test both occurred between the primer and top coat.

3.8 Overall Results

As a result of these evaluations it is evident that the solvent based epoxy mastic system is superior to all of the other systems tested.

In a discussion with the manufacturer concerning the possibility of using a thin mastic as a primer and a second system as a top coat, his feeling is that it would only be possible if the top coat was an epoxy system; however, it was not recommended.

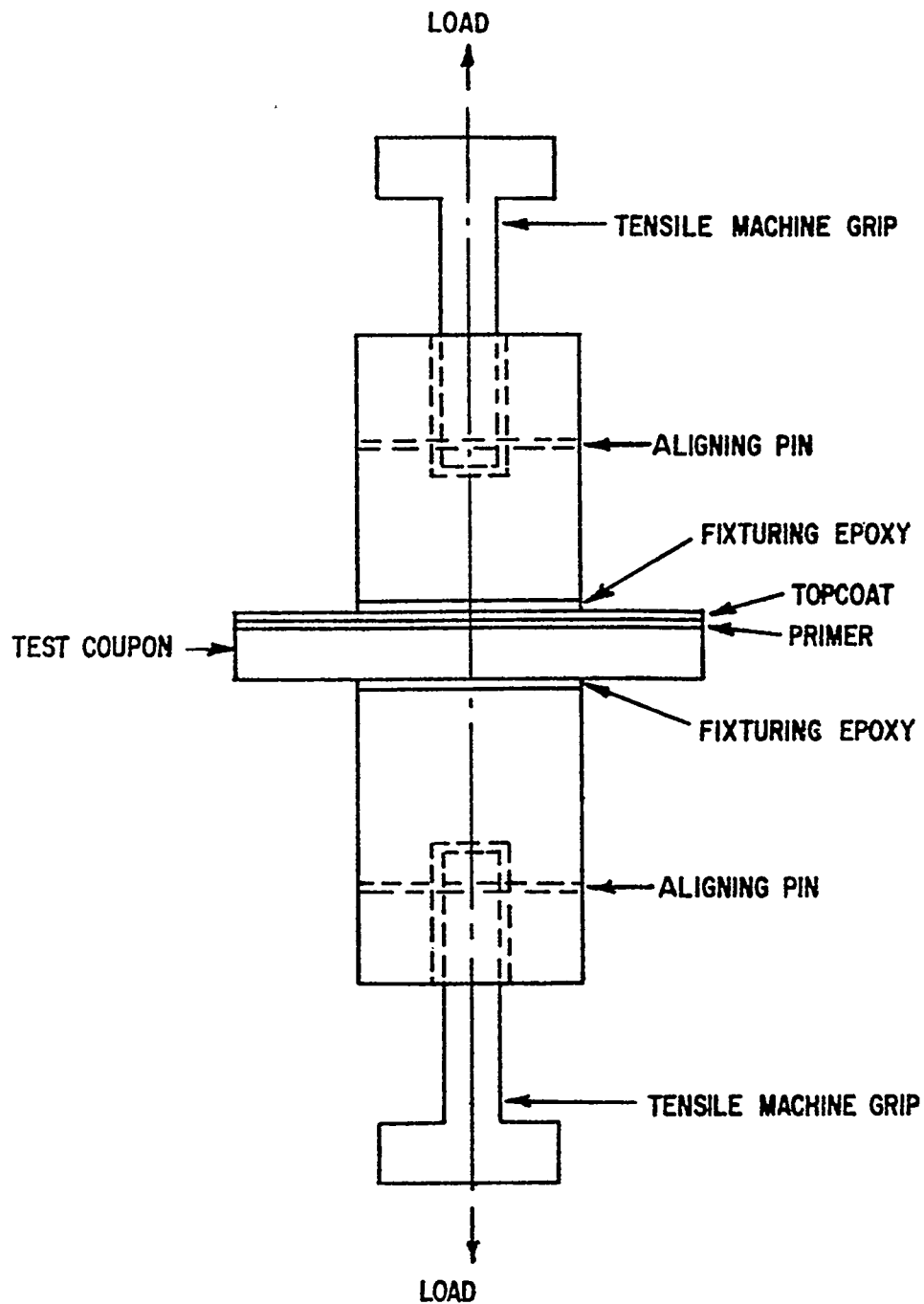


Figure 3.18 Schematic Diagram of the Essential parts of the Bond Strength Apparatus

TABLE V
BOND STRENGTH RESULTS BEFORE AND AFTER EXPOSURE
0 1000 HOURS IN SALT WATER

Candidate Coating System P-Primer, Tc-Top Coat	A - Bond Strength Before Exposure PSi	B - Bond Strength After Exposure PSi	Remarks Location of Failure
Latex Mastic	550	335	A-Substrate B-Coating
Epoxy Mastic Water Base	780	620	A-Substrate B-Substrate
Epoxy Mastic Solvent Base	985	936	A-Substrate B-Substrate
P950/Tc Urethane	810	545	A-Primer/Top Coat B-Substrate
P950/Tc-Epoxy	620	480	A-Primer/Top Coat B-Substrate
P600/Tc Alkyd	310	110	A-Substrate B-Substrate
P250/Tc Alkyd	220	70	A-Substrate B-Substrate
P-Fish Oil/Tc Alkyd	110	30	A-Primer/Top Coat B-Primer/Top Coat
P-Fish Oil/Tc Epoxy	90	45	A-Primer/Top Coat B-Primer/Top Coat
P-Latex Conversion/Tc Chlorinated	200	20	A-Primer/Top Coat B-Substrate
P-Latex Conversion/ Epoxy	150	22	A-Primer/Top Coat B-Substrate
P-Latex Conversion/ Alkyd	115	18	A-Substrate

REFERENCES

REFERENCES

1. Fultz, B.S., Cleaning of Steel Assemblies and Shipboard "Touch-up Using Citric Acid," U.S. Department of Commerce Maritime Administration, May 1980.
2. Cupr, Von, V., and Cibulka, B., Aufbereitung Von Stahl-und Eisenoberflächen durch eine Mineral schicht. Werkstoffe und Korrosion, Volume 10, 1967.
3. Dasgupta, D. and Ross, T.K., Inertization of Rusty Steel for Painting. Brit. Corrosion J., Nov. 1971, 6, (6), 241-243.
4. Gardner and Sword, Paint Testing Manual STP 500, Thirteenth Edition, 1972, ASTM.

APPENDIX A

Literature Search



Protection Against Marine Corrosion. Anti-Corrosion Methods Mat., May 1969, 16, (5), 12, 14-16 [in English].

Anti-Corrosion Review : Permanent Treatments. Eng. Mat. Design. Sept. 1971, 14, (8), 777-780 [in English].

'Inertization' of Rusty Steel for Painting. D. Dasgupta and T. K. Ross. Brit. Corrosion J., Nov. 1971, 6, (6), 241-243 [in English].

The Role of Rust Converters in Painting of Corroded Steel. S. Guriuviah, M. Sundaram, C. Rajagopal, and K. S. Rajagopalan, Anticorros. Methods May 1980, 27, (5), 8-10, [in English].

The Use of Rust Converters in the Application of Paint Materials for the Protection of Steel Storage Tanks. Z.A. Popova. Korroziya i Zashchita, 1974, (10), 22-23 [in Russian].

The Effect of Rust Transition and Stabilization with Cortanin Preparation on the Life and Effectiveness of Anticorrosive Coatings. G. Wi eczorck, J. Gust, and E. Smieszek. Ochr. Przed Koroz. Nov. 1979, 22, (11), 288-294, [in Polish].

Some Data on the Use of Noverox Rust Converter. J. Kovacs. Korroz. Figyel.o. 1979, (19), (4), 131-132 [in Hungarian].

The Effect of a Penetrating Compound on the Electrical Conductivity of the Corroded Surface Layers of Steel and the Protective Properties of the Compound Against Corrosion in Marine Atmospheres. A. G. Khanlarova, S. N. Selimova, and S. A. Ali-Zade. Korroz. Zashch., 1977, (5), 17-20 [in Russian].

Metal Coating by a Rust Transformer Acting at Room Temperature. Zoltan Vargha. Corrosion Week, Budapest, Oct. 1968, 1970, 467-471 (Met. A., 7005-72 0128) [in English].

Coatings upon Rust. Fritz Gonnell. Corrosion Week, Budapest, Oct. 1968, 1970, 410-420 (Met. A., 7005-72 0128) [in German].

The Use of a Rust Converter in Anti-Corrosion Technology. I. M. Favorskaya and V. A. Voitovich. Korroz. Zashch., 1977, (2), 30-31 [in Russian].

Anticorrosive and Marine Paints. M. L. Ellinger. Paint Manufacture, May 1972, 42 (5), 30-32 [in English].

The Priming of Imperfectly De-Rusted Surfaces. Luwiczka Bulczynska and Andrzej Kwiatkowski. Ochrona Przed Korozja, June 1971, 14, (6), 18-21 [in Polish].

'Painting over Rust' and the Application of 'Rust Stabilisers : Wolfgang Eibisch. Korrosionsschutzprobleme, 1969, 32-39 (Met. A., 7001-72 0026) [in German].

Stabilization and Neutralization of Rust Used as a Surface Preparation for Painting. V Sourek and J. Kos. Koroze a Ochrana Mat., 1971 15, (1), 8-10 [in Czech].

The Kinetic of Corrosion, Passivation and Inhibition of Iron Group Metals. K. Schwabe. Wiss. Z. Techn. Hochschule Otto von Guericke, 1970, 14, (1), 67-76 [in German].

Maintenance-Free Service of Weathering Steel by Rust Stabilization Accelerating Treatment. (Pamphlet). T. Sakai, and S. Tokunaga. Corrosion '79 [proc. Conf] Atlanta, Ga., 12-16 March 1979. National Assoc. of Corrosion Engineers, P.O. Box 986, Katy, Tex. 77450, 1979. Pp 12. [in English].

The Best Way to Paint Structural Steel : A Re-Appraisal. J. F. Stanners. BISRA Open Report No.C/41/68. BISRA, Inter-Group Laboratories of the British Steel Corp., 24 Buckingham Gate, London SW1. 1968, Pp 15 [Pamphlet-English].

[Rust Stabilization.] A New Way to Fight Corrosion. -. Anticorros. Methods Mater., Oct. 1975, 22, (10), 9-10 [in English].

The Corrosion and Protection Centre at U.M.I.S.T. [University of Manchester Institute of Science and Technology]. II.-Research. N. Ashworth and R.P.M. Procter. Anti-Corrosion Methods Mat., Oct. 1972, 19, (10), 9-10 [in English].

Use of Rust Converters in Engineering. V. A. Voitovich and I. M. Favorskaya. Vestnik Mashinostroeniya, Jan. 1975, (1), 66-67 [in Russian].

Surface Treatment of Steel and Iron by Application of Mineral Coatings. V. Cupr and B. Cibulka, Werkstoffe u. Korrosion, Oct. 1967, 18, (10), 878-882.

Corrosion and Corrosion Protection. VII A.-Corrosion Protection by Conversion Coating. Wilhelm Wiederholt. VDI Z., Aug. 1970, 112, (16), 1113-1119 [in German].

Comparison of Various Corrosion-Protective Coatings. J. Sickfeld and D. Wapler. Werkstoffe u. Korrosion, Feb. 1970, 21, (2), 77-85 [in German].

Preparation of Steel Surfaces Before the Application of Coatings for Corrosion Protection. H. Mayfarth. Technik, June 1968, 23, (6), 377-381 [in German].

A De-Rusting Agent with an [Accompanying] Passivation Effect Based Upon EDTA ($C_{10}H_{16}N_2O_8$) and the Zn-EDTA Complex. V. Ruml. MetallOberflache Mar. 1968, 22, (3), 70-74.

The Stabilizing Treatment of Rusty Iron and Steel Surfaces. P. 1. V. Cupr and B. Cibulka. Deut. Farbn Z., Oct. 1967, 21, (10), 494-500 [in German].

The Stabilizing Treatment of Rusty Iron and Steel Surfaces. P. 2.
V. Cupr and B. Cibulka. Deut. Farb Z., Nov. 1967, 21, (11), 541-546
[in German].

Anticorrosive and Marine Paints. M. L. Ellinger. Paint Manufacture,
Jan. 1972, 42, (1), 26-28 [in English].

Preparation for Painting. Norman I. Gaynes. Met. Finish. (Guidebook and Directory), 1972, 576, 578, 580-589 [in English].

Concerning Rust Stabilizers. C. F. Hickethier. Ing.Ind. (Supplement no.13). Jan-Feb. 1968, 34, (391), 3-8. [in Spanish].

The Effect of the Rust Converter PE-2 on the Mechanical Properties of Steel St3₀. S. N. Salimova, A. G. Khanlarova, S. A. Aleskerova, K. B. Ismailova, and K. M. Mekhtiev. Korroziya, 1980, (1), 8-11. [in Russian].

Chemical Treatment of Rusty Steel Surfaces with Contamin Anticorrosive Preparation. J. Gust, and G. Wieczorek. Ochr. Przed Koroz., Dec. 1979, 22, (12), 323-328. [in Polish].

APPENDIX B

List of Companies Contacted



COMPANIES CONTACTED

Devoe Paint Division
BOX 1863
Louisville, KY

Mr. V. Datta

Cook Paint and Varnish Co.
919 T E. 14th Ave.
North Kansas City, MO 64116

Seaguard Corp.
4030 T. Seaguard Ave.
Portsmouth, VA 23705

Carboline Co.
350 Hanley Industrial Court
St. Louis, MO 63144

Farboil Co.
8200 Fischer Rd.
Baltimore, MD 21222

Hughson Chemicals
Hughson Building
P.O. Box 1099
Erie, PA 16512

Mr. R. Wigmon

Sigma Coatings Inc.
P.O. Box 826
Hawey, LA 70059

Mr. M. Winkler

Himpel's Marine Paints Inc.
25 Broadway Cunard Bldg.
New York, N.Y. 10004

American Chemical Corp.
81-T Encina Ave.
Palo Alto, CA 94301

Mr. W. L. Warne

The TapeCoat Co.
1525 Lyons St.
Evanston, IL 60204

Companies contacted - continued

Turco Coating Inc.
Wheatland & Mellons St.
Phoenixville, PA 19460

Woolsey Marine Industrial Inc.
180-T Saw Mill Road
Danbury, CT 06810

International Paint Co., Inc.
17 Battery Place N.
New York, NY 10004

Mr. J. Hickey

Xerox Corp.
500 West Eight St.
Suite 235, P.O. Box E
Vancouver, WA 98666

Mr. D. Woodey

Teknos-Moalito Oy
P.O. 10700101
Helsinki 10, Finland

Mr. E. Taskenen

Applied Coating Tech. Inc.
1735 Austin Ave.
Los Altos, California 94022

Mr. E. Shapes

Bywater Marine Coating
709 Engineers Rd.
Belle Chasse, LA 70037

Mr. Wirstrom

Rust-Oleum
11 Hawthorn Parkway
Vernon Hill, IL 60061

Union Carbide
Coating Materials Dist.
300 First Ave.
Needham Heights
Boston, MA 02194

Mr. R. S. Marten

Diffusalloy Engineering Co.
10097 Manchester Road
St. Louis, MO 63122

APPENDIX C

Information Sheet



RUST COMPATIBLE PRIMER INFORMATION

Vendors Name _____

Coating Designation _____ Generic Base _____

DO NOT CLEAN SURFACE

Method of application (air or airless spray, brush etc.) _____

Is special equipment required for application _____

If so, what type _____

Application Conditions

Temperature _____ Relative Humidity _____

Number of coats applied _____

Is a top coat necessary? _____

Was a top coat applied? _____ Type _____

What type of top coats are compatible with this primer (alkyd, water base, etc)?

Curing Method _____

Coating Description (Water base, oil base, non-solvented etc.) _____

Color _____

Number of components-primer _____ Top coat _____

Possible reason for suitability of coating over rust (conversion coating, moisture barrier etc.) _____

Specimen

Fresh Water

F _____

F _____

F _____

F _____

Salt Water

S _____

S _____

S _____

S _____

Moist Air

M _____

M _____

M _____

M _____

Remarks _____

Please send application instructions with test specimens.

Person to contact concerning test specimen

Signature _____

Telephone Number _____